ART. XVIII.—*On the Black Bulb Thermometer as a measure of the Temperature of Solar Radiation.* By Mr. R. L. J. ELLERY, F.R.A.S., Government Astronomer, &c., President of the Royal Society of Victoria.

[Read 12th October, 1868.]

On the 24th February I read a short paper giving the results of a series of observations of solar radiation, by which I showed that, so far as my observations then went, the ordinary black glass bulb thermometer did not indicate by many degrees the true temperature of the sun's rays, more especially when the solar radiation was large. It further appeared that a thermometer whose bulb was covered with a coating of lamp-black and size gave far more reliable indications ; and I pointed out that this was probably owing to the diathermancy of nearly all black glass to the obscure heat rays ; permitting them to reach the surface of the mercury inside the bulb, which reflected them back into space.

Since then I have obtained a long series of observations with the same two thermometers, as well as with two others from the Adelaide Observatory, sent to me by Mr. Todd, the results of which do not confirm my former conclusions as to the causes of the differences of indications exhibited by the thermometers then used, but rather lead me to the belief that the *Indications of Black bulb Thermometers generally, as a measure of the Temperature of Solar Radiation are unreliable.*

The thermometers used were four—

No. 1. Thermometer by Grimoldi, of Melbourne, with bulb covered by lamp-black.

2. Thermometer by Casella, of London. Black glass bulb.

3. Thermometer by Negretti and Zambra, of London. Black glass bulb.

Being as follows :—

No. 1	=	— 0·2		No. 3	=	+ 0·3	
2	=	— 2°·0		4	=	... 0·0.	

All four were placed on a suitable stand in the open air, with their bulbs exposed to the sun's rays under exactly similar conditions and their indications, which showed the highest

temperature they had registered during the previous twenty-four hours, were read every morning at nine o'clock. Readings were also obtained at various times throughout clear days so as obtain their indications at other periods than those of maximum radiation.

No. 4. Thermometer by Negretti and Zambra, of London. Black glass bulb.

Nos. 1 and 2 are enclosed in outer protecting tubes of glass, exhausted of air and hermetically sealed ; the enclosing bulbs are about one-inch diameter.

In Nos. 3 and 4 the enclosing tubes are larger than 1 and 2, and are from one-and-a-half to two-and-a-half inches diameter.

No. 4 was compared at Greenwich, and is certified to be correct from 32° to 100°.

In the first place, all these thermometers were compared in heated water with a standard thermometer, and found to have similar corrections amongst themselves at high temperature as at low ones.

These readings were tabulated and the results are as follows :—

No. 1. Lampblack Bulb.	No. 2. B. Glass.	No. 3. B. Glass.	No. 4. B. Glass.
When No. 1 reads from.	Correction.	Correction.	Correction.
60° to 70°	— 3·3	+ 0·7	— 0·7
70 to 80	— 5·3	+ 2·1	— 1·2
80 to 90	— 8·1	+ 5·1	— 0·9
90 to 95	— 9·8	+ 14·9	— 2·2
95 to 100	— 11·3	+ 14·1	+ 1·8
100 to 105	— 11·6	+ 14·5	+ 0·9
105 to 110	— 12·0	+ 14·1	+ 0·4
110 to 115	— 11·1	+ 14·9	+ 0·1
115 to 120	— 12·4	+ 13·7	— 0·8
120 to 130	— 12·9	+ 12·6	— 1·3
130 to 140	— 13·7	+ 10·0	— 2·8

I then tried them by exposing them to heat radiated from a dark body, thus : A sheet of copper, one foot square, with a dull surface, was placed perpendicularly, and a large Bunsen's burner made to play on one of its surfaces, so as to heat it at about the centre. Thermometers Nos. 1 and 2 were now arranged on a stand, so that their bulbs were both as nearly as possible three inches from the centre of the

other surface of the sheet of copper. As the copper got heated and radiated, the thermometers commenced slowly to rise until they reached an indicated temperature of 150°, when the burner was removed and the temperature fell to about 80°. Readings were obtained at every 10°, both whilst they were rising and falling. Nos. 3 and 4 were compared with No. 1 in the same way. The results were as follows: No. 2 behaved almost exactly as it did under solar heat; the difference between its indications and those of No. 1 increasing with the temperature until when No. 1 read 145°, No. 2 indicated only 130°.

No. 3 was exceedingly slow in rising. At 90° with No. 1 it was 12° behind; at 100°, 70° behind; and at 120° it was 23°; at 150°, however, it was only 14°·5. The highest temperature indicated by No. 1 was 150°, while No. 3 reached 140° a considerable period after No. 1 had ceased to rise. A second experiment gave almost identical results. It was found, however, that No. 3 continued to increase its indications after the source of heat was removed, but never reached the temperature indicated by No. 1. In cooling, too, it fell very slowly, reading 125° when No. 1 read 109°, and so on. The surrounding bulb is about two and a half inches diameter, and of very thick glass. It remained hot a long time after the bulb of No. 1 was quite cool. No. 4 was now tried against Nos. 1 and 3. The relations between 1 and 3 were the same as before, while No. 4 (the one tested at Greenwich) read 3° more than No. 1 at 80°, 6° more at 120°, 5° at 138°, and 3° at 145°; and they increased and decreased in their indications simultaneously. No. 4 has a surrounding bulb of about one inch and three-quarters and the glass is thin, while that of No. 1 is about one inch diameter and of somewhat thick glass.

These results are not quite confirmatory of the belief which I expressed in my former paper, that coating the black glass bulb with some dead opaque pigment, so as to destroy every trace of diathermancy, would render the indications of solar radiation thermometers more reliable and intercomparable. The anomalous results obtained from No. 3 are somewhat inexplicable. Exposed to the sun's rays this thermometer always indicates the highest temperature of all four; exposed to radiant heat from a dark surface it is quite the reverse; it is found to be exceedingly slow in absorbing the heat rays, and equally slow in parting with them; and it was observed that the mercury continued to rise for several

minutes after the source of heat was removed—it would almost seem as if the thick surrounding bulb intercepted the heat rays and stored them, giving them out slowly to the black bulb after the external feed had ceased. No. 4 (the one tested at Greenwich) which has an ordinary black glass bulb with a thin surrounding bulb, was the quickest to absorb the heat from the dark body, and indicated the highest temperature of all four. The one with the blackened bulb (No. 1) was the next in order, and rose almost as rapidly as No. 4, but fell short of its indication by 6° at temperatures above 120°. These two read nearly alike at all temperatures when exposed to the sun.

So far as these observations go, they seem to show that the usual methods of measuring the "heat in the sun" are fallacious; that among four excellent black bulb thermometers from good makers the differences at high temperatures are sometimes as much as 28° Fahrenheit; and when one is bearing sun's rays at 145° or 150° it is certainly not satisfactry too find the thermometers indicating only about 120° or 125°. We may, I think, safely conclude that some more reliable and accurate instruments are required for the purpose than those usually adopted; ann although it is probable that a careful selection of the glass used and a strict adherence to one form, size, and as near as possible the same thickness in the construction of the outer bulb, would reduce the discrepancies to a large extent, there is something more required in the material of the black bulb itself than usually exists in these now used. Tyndal, in his little book on *Radiation*, note page 29, says: "The black glass chosen for thermometers, ahd intended to absorb completely the solar heat, may entirely fail in this object if the glass in which the carbon is incorpored be colourless. To render the bulb of a thermometer a perfect absorbent, the glass with which the carbon is incorporated ought in the first instance to be green."

This may be accepted as the best way to make the black glass bulbs; but it is also essential, I believe, to have the surface dead, and not polished, as the ordinary surface of glass always is. With bulbs made of such glass, with the surface deadened, we should probably have a reliable thermometer; but the necessity for protecting the bulb from currents of air involves other questions which I have pointed out, and which I believe, require fnrther experiment for their solution.